

UNITED STATES PATENT APPLICATION FOR:

AN EXPANDABLE HANGER AND PACKER

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AN EXPANDABLE HANGER AND PACKER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of copending U.S. Patent Application Serial No. 10/132,424, filed April 25, 2002, which is a continuation-in-part of issued U.S. Patent No. 6,688,399, issued February 10, 2004, which are incorporated in their entirety by reference herein.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to wellbore completion. More particularly, the invention relates to an apparatus and method for creating an attachment and a seal between two tubulars in a wellbore.

Description of the Related Art

[0003] In the drilling of oil and gas wells, a wellbore is formed using a drill bit that is urged downwardly at a lower end of a drill string. After drilling a predetermined depth, the drill string and bit are removed, and the wellbore is lined with a string of steel pipe called casing. The casing provides support to the wellbore and facilitates the isolation of certain areas of the wellbore adjacent hydrocarbon bearing formations. The casing typically extends down the wellbore from the surface of the well to a designated depth. An annular area is thus defined between the outside of the casing and the earth formation. This annular area is filled with cement to permanently set the casing in the wellbore and to facilitate the isolation of production zones and fluids at different depths within the wellbore.

[0004] It is common to employ more than one string of casing in a wellbore. In this respect, a first string of casing is set in the wellbore when the well is drilled to a first designated depth. The well is then drilled to a second designated depth, and a second string of casing, or liner, is run into the well to a depth whereby the upper portion of the second liner is overlapping the lower portion of the first string of casing. The second liner string is then fixed or hung in the wellbore, usually by some mechanical slip mechanism well-known in the art, and cemented. This

process is typically repeated with additional casing strings until the well has been drilled to total depth.

[0005] After the initial string of casing is set, the wellbore is drilled to a new depth. An additional string of casing, or liner, is then run into the well to a depth whereby the upper portion of the liner, is overlapping the lower portion of the surface casing. The liner string is then fixed or hung in the wellbore, usually by some mechanical slip mechanism well known in the art, commonly referred to as a hanger.

[0006] Downhole tools with sealing elements are placed within the wellbore to isolate areas of the wellbore fluid or to manage production fluid flow from the well. These tools, such as plugs or packers, for example, are usually constructed of cast iron, aluminum or other alloyed metals and include slip and sealing means. The slip means fixes the tool in the wellbore and typically includes slip members and cores to wedgingly attach the tool to the casing well. In addition to slip means, conventional packers include a synthetic sealing element located between upper and lower metallic retaining rings.

[0007] The sealing element is set when the rings move towards each other and compress the element there between, causing it to expand outwards into an annular area to be sealed and against an adjacent tubular or wellbore. Packers are typically used to seal an annular area formed between two coaxially disposed tubulars within a wellbore. For example, packers may seal an annulus formed between production tubing disposed within wellbore casing. Alternatively, packers may seal an annulus between the outside of the tubular and an unlined borehole. Routine uses of packers include the protection of casing from pressure, both well and stimulation pressures, as well as the protection of the wellbore casing from corrosive fluids. Other common uses include the isolation of formations or leaks within a wellbore casing or multiple production zones, thereby preventing the migration of fluid between zones. Packers may also be used to hold fluids or treating fluids within the casing annulus in the case of formation treatment, for example.

[0008] One problem associated with conventional sealing and slip systems of conventional downhole tools relates to the relative movement of the parts necessary in order to set the tools in a wellbore. Because the slip and sealing means require parts of the tool to be moved in opposing directions, a run-in tool or other mechanical device must necessarily run into the wellbore with the tool to create the movement. Additionally, the slip means takes up valuable annular space in the wellbore. Also, the body of a packer necessarily requires wellbore space and reduces the bore diameter available for production tubing, etc.

[0009] A recent trend in well completion has been the advent of expandable tubular technology. It has been discovered that both slotted and solid tubulars can be expanded *in situ* so as to enlarge the inner diameter. This, in turn, enlarges the path through which both fluid and downhole tools may travel. Also, expansion technology enables a smaller tubular to be run into a larger tubular, and then expanded so that a portion of the smaller tubular is in contact with the larger tubular therearound. Tubulars are expanded by the use of a cone-shaped mandrel or by an expander tool with expandable, fluid actuated members disposed on a body and run into the wellbore on a tubular string. During expansion of a tubular, the tubular walls are expanded past their elastic limit. Examples of expandable tubulars include slotted screen, joints, packers, and liners. The use of expandable tubulars as hangers and packers allows for the use of larger diameter production tubing, because the conventional slip mechanism and sealing mechanism are eliminated.

[0010] While expanding tubulars in a wellbore offers obvious advantages, there are problems associated with using the technology to create a hanger or packer through the expansion of one tubular into another. By plastically deforming the tubular, the cross-sectional thickness of the tubular is necessarily reduced. Simply increasing the initial cross-sectional thickness of the tubular to compensate for the reduced tensile strength after expansion results in an increase in the amount of force needed to expand the tubular.

[0011] More importantly, when compared to a conventional hanger, an expanded tubular with no gripping structure on the outer surface has a reduced capacity to support the weight of a liner. This is due to a reduced coefficient of friction of the outer surface of an expandable tubular in comparison to the slip mechanism having teeth or other gripping surfaces formed thereon. In another problem, the expansion of the tubular in the wellbore results in an ineffective seal between the expanded tubular and the surrounding wellbore.

[0012] A need therefore exists for an expandable tubular connection with increased strength. There is a further need for an expandable tubular connection providing an improved gripping surface between an expanded tubular and an inner wall of a surrounding tubular. Yet a further need exists for an expandable tubular configured to allow metal flow upon expansion to insure contact and sealing capabilities between an expanded tubular and an inner wall of a surrounding tubular. There is yet a further need for an expandable tubular with an increased capacity to support the weight of a liner.

SUMMARY OF THE INVENTION

[0013] The present invention generally relates to an apparatus and method for engaging a first tubular and a second tubular in a wellbore. The present invention provides a tubular body formed on a portion of a first tubular. The tubular body is expanded so that the outer surface of the tubular body is in frictional contact with the inner surface of a surrounding second tubular. In one embodiment, the tubular body is modified by machining grooves and profile cuts into the surface, thereby reducing the amount of radial force required to expand the tubular body on the first tubular into the surrounding tubular.

[0014] The tubular body optionally includes hardened inserts, such as carbide buttons, for gripping the surrounding tubular upon contact. The gripping mechanism increases the capacity of the expanded tubular to support its weight and to serve as a hanger. In another aspect, the outer surface of the expandable tubular body optionally includes a pliable material such as an elastomer within grooves and profile

cuts formed on the outer surface of the tubular for increasing the sealing capability of the expandable tubular. As the tubular is expanded, metal flow causes the profile cuts to close up, thereby causing the pliable material to extrude outward. This extrusion of the pliable material insures contact with the casing and improves the sealing characteristics of the interface between the expanded tubular and the casing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] So that the manner in which the above recited features and advantages of the present invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

[0016] It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0017] Figure 1 is a perspective view of a tubular having profile cuts that intersect corners of the grooves formed in the outer surface, and having inserts of a hardened material also disposed around the outer surface.

[0018] Figure 2 is a section view of the tubular of Figure 1.

[0019] Figure 3 is an exploded view of an exemplary expander tool.

[0020] Figure 4 is a partial section view of a tubular of the present invention within a wellbore, and showing an expander tool attached to a working string also disposed within the tubular.

[0021] Figure 5 is a partial section view of the tubular of Figure 4 partially expanded by the expander tool.

[0022] Figure 6 is a partial section view of an expanded tubular in the wellbore with the expander tool and working string removed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0023] Figure 1 is a perspective view of the apparatus of the present invention. The apparatus 200 defines a tubular body formed on a portion of a larger tubular. The tubular body 200 shown in Figure 1 includes a series of relief grooves 210 and profile cuts 205 machined into the outer surface. However, it is within the scope of the present invention to machine some or all of the grooves 210 into the inner surface of the expandable tubular 200. The relief grooves 210 and profile cuts 205 serve to reduce the thickness of the tubular 200, thereby reducing the amount of material that must be plastically deformed in order to expand the tubular 200. This reduction in material also results in a reduction in the amount of force needed to expand the tubular 200.

[0024] As shown in Figure 1, the grooves 210 are machined in a defined pattern. Employment of a pattern of grooves 210 serves to increase the tensile properties of the tubular 200 beyond those of a tubular with straight grooves simply cut around the circumference of the tubular. This improvement in tensile properties is due to the fact that the variation in cross-sectional thickness will help to prevent the propagation of any cracks formed in the tubular. The pattern of grooves depicted in Figure 1 is a continuous pattern of grooves 210 about the circumference of the body 200, with the grooves 210 intersecting to form a plurality of substantially identical shapes. In the preferred embodiment, the shapes are diamonds. However, the scope of this invention is amenable to other shapes, including but not limited to polygonal shapes, and interlocking circles, loops or ovals (not shown).

[0025] In one embodiment, the profile cuts 205 are formed on the surface of the shapes created by the grooves 210. The profile cuts 205 are formed at a predetermined depth less than the grooves 210 so that the profile cuts 205 will not substantially affect the compressive or tension capabilities of the tubular 200 upon expansion. The profile cuts 205 may be horizontal cuts, vertical cuts or combinations thereof to divide each shape into two or more portions. Preferably, the profile cuts 205 intersect the corners of the grooves 210 as depicted on Figure 1.

[0026] Figure 1 also depicts inserts 220 interdisposed within the pattern of grooves 210 and profile cuts 205. The inserts 220 provide a gripping means between the outer surface of the tubular 200 and the inner surface of a larger diameter tubular (not shown) within which the tubular 200 is coaxially disposed. The inserts 220 are made of a suitably hardened material, and are attached to the outer surface of the tubular 200 through a suitable means such as soldering, epoxying or other adhesive method, or via threaded connection. In the preferred embodiment, carbide inserts 220 are press-fitted into preformed apertures in the outer surface of tubular body 200. After expansion, the inserts 220 are engaged with the inner surface of a larger diameter tubular (not shown), thereby increasing the ability of the expanded tubular 200 to support the weight of the tubular below the expanded portion.

[0027] In the embodiment shown in Figure 1, carbide inserts 220 are utilized as the gripping means. However, other materials may be used for fabrication of the inserts 220 so long as the inserts 220 are sufficiently hard to be able to grip the inner surface of an outer tubular during expansion of the tubular body 200. Examples of fabrication materials for the inserts 220 include ceramic materials (such as carbide) and hardened metal alloy materials. The carbide inserts 220 define raised members fabricated into the tubular body 200. However, other embodiments of gripping means may alternatively be employed. Such means include but are not limited to buttons having teeth (not shown), or other raised or serrated members on the outer surface of the expandable tubular 200. Alternatively, the gripping means may define a plurality of hardened tooth patterns added to the outer surface of the tubular body 200 between the grooves 210 themselves.

[0028] The embodiment of Figure 1 also depicts a pliable material 230 disposed within the grooves 210 and profile cuts 205. The pliable material 230 increases the ability of the tubular 200 to seal against an inner surface of a larger diameter tubular upon expansion. In the preferred embodiment, the pliable member 230 is fabricated from an elastomeric material. However, other materials are suitable which enhance the fluid seal sought to be obtained between the expanded portion of tubular 200 and an outer tubular, such as surface casing (not shown). The pliable material 230

is disposed within the grooves 210 and profile cuts 205 by a thermal process, or some other well known means. A thin layer of the pliable material 230 may also encapsulate the inserts 220 and facilitate the attachment of the inserts 220 to the tubular 200.

[0029] Figure 2 is a section view of a portion of the tubular 200 of Figure 1. In this view, the inserts 220 are shown attached to the tubular 200 in the areas between the grooves 210 and at an intersection of the profile cuts 205. In this respect, the inserts 220 are interdispersed within the pattern of grooves 210 and profile cuts 205. Figure 2 also clearly shows the reduction in cross-sectional thickness of the tubular 200 created by the grooves 210 and profile cuts 205 before expansion. Figure 2 further shows the profile cuts 205 formed at a depth less than the grooves 210.

[0030] The inserts 220 in Figure 2 have a somewhat conical shape projecting from the outer surface of the tubular 200 to assist in engagement of the inserts 200 into an outer tubular (shown in Figure 4). For clarity, the inserts are exaggerated in the distance they extend from the surface of the tubular. In one embodiment, the inserts extend only about 0.03 inches outward prior to expansion. In another embodiment, the raised members 220 are initially recessed, either partially or completely, with respect to the tubular 200, and then extend at least partially outward into contact with the casing after expansion. Such an embodiment is feasible for the reason that the wall thickness of the tubular 200 becomes thinned during the expansion process, thereby exposing an otherwise recessed raised member.

[0031] The tubular body 200 of the present invention is expanded by an expander tool 100 acting outwardly against the inside surface of the tubular 200. Figure 3 is an exploded view of an exemplary expander tool 100 for expanding the tubular 200. The expander tool 100 has a body 102, which is hollow and generally tubular with connectors 104 and 106 for connection to other components (not shown) of a downhole assembly. The connectors 104 and 106 are of a reduced diameter compared to the outside diameter of the longitudinally central body part of the tool 100. The central body part 102 of the expander tool 100 shown in Figure 3 has

three recesses 114, each holding a respective roller 116. Each of the recesses 114 has parallel sides and extends radially from a radially perforated tubular core (not shown) of the tool 100. Each of the mutually identical rollers 116 is somewhat cylindrical and barreled. Each of the rollers 116 is mounted by means of an axle 118 at each end of the respective roller 116 and the axles are mounted in slidable pistons 120. The rollers 116 are arranged for rotation about a respective rotational axis that is parallel to the longitudinal axis of the tool 100 and radially offset therefrom at 120-degree mutual circumferential separations around the central body 102. The axles 118 are formed as integral end members of the rollers 116, with the pistons 120 being radially slidable, one piston 120 being slidably sealed within each radially extended recess 114. The inner end of each piston 120 is exposed to the pressure of fluid within the hollow core of the tool 100 by way of the radial perforations in the tubular core. In this manner, pressurized fluid provided from the surface of the well, via a working string 310, can actuate the pistons 120 and cause them to extend outward whereby the rollers 116 contact the inner wall of a tubular 200 to be expanded.

[0032] Figure 4 is a partial section view of a tubular 200 of the present invention in a wellbore 300. The tubular 200 is disposed coaxially within the casing 400. An expander tool 100 attached to a working string 310 is visible within the tubular 200. Preferably, the tubular 200 is run into the wellbore 300 with the expander tool 100 disposed therein. The working string 310 extends below the expander tool 100 to facilitate cementing of the tubular 200 in the wellbore 300 prior to expansion of the tubular 200 into the casing 400. A remote connection (not shown) between the working, or run-in, string 310 and the tubular 200 temporarily connects the tubular 200 to the run-in string 310 and supports the weight of the tubular 200. In one embodiment of the present invention, the temporary connection is a collett (not shown), and the tubular 200 is a string of casing.

[0033] Figure 4 depicts the expander tool 100 with the rollers 116 retracted, so that the expander tool 100 may be easily moved within the tubular 200 and placed in the desired location for expansion of the tubular 200. Hydraulic fluid (not shown) is

pumped from the surface to the expander tool 100 through the working string 310. When the expander tool 100 has been located at the desired depth, hydraulic pressure is used to actuate the pistons (not shown) and to extend the rollers 116 so that they may contact the inner surface of the tubular 200, thereby expanding the tubular 200.

[0034] Figure 4 also shows the carbide inserts 220 attached to the outer surface of the tubular 200. Because the tubular 200 has not yet been expanded, the carbide inserts 220 are not in contact with the casing 400 so as to form a grip between the tubular 200 and casing 400. Figure 4 also shows the pliable material 230 disposed within the grooves 210 and the profile cuts 205.

[0035] Figure 5 is a partial section view of the tubular 200 partially expanded by the expander tool 100. At a predetermined pressure, the pistons (not shown) in the expander tool 100 are actuated and the rollers 116 are extended until they contact the inside surface of the tubular 200. The rollers 116 of the expander tool 100 are further extended until the rollers 116 plastically deform the tubular 200 into a state of permanent expansion. The working string 310 and the expander tool 100 are rotated during the expansion process, and the tubular 200 is expanded until the tubular's outer surface contacts the inner surface of the casing 400. As the tubular 200 contacts the casing 400, the inserts 220 begin to engage the inner surface of the casing 400.

[0036] The grooves 210 are also expanded during this expansion process, thereby causing some of the metal around the grooves 210 to flow away from the grooves 210. The metal flow is redistributed in the shallower profile cuts 205, thereby closing the profile cuts 205. As the profile cuts 205 close, the pliable material 230 in the profile cuts 205 extrudes outward into contact with the casing 400. Further, the pliable material 230 in the grooves 210 fills a space remaining between the grooves 210 and the casing 400. After the pliable material 230 contacts the casing 400, the interface between the expanded tubular 200 and the casing 400 is sealed. The

working string 310 and expander tool 100 are then translated within the tubular 200 until the desired length of the tubular 200 has been expanded.

[0037] Figure 6 is a partial section view of an expanded tubular 200 in a wellbore 300, with the expander tool 100 and working string 310 removed. Figure 6 depicts the completed expansion process, after which the expanded portion of the tubular 200 defines both a packer and a hanger. As a packer, the expanded portion of the tubular 200 seals the annular area between the casing 400 and the tubular 200. As a hanger, the expanded portion of the tubular 200 supports the weight of the tubular 200.

[0038] Figure 6 shows the engagement between the inserts 220 and the inner surface of the casing 400. The engagement enables the expanded portion of the tubular 200 to support an increased weight in comparison to an expanded tubular without inserts. The inserts 220 axially and rotationally fix the outer surface of the expanded tubular 200 to the inner surface of the casing 400. Further, the profile cuts 205 are closed and the pliable material 230 that was in the profile cuts 205 and the grooves 210 is disposed in the interface between the expanded tubular 200 and the casing 400.

[0039] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be directed without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.